

Evaluation of cement-excelsior boards made from yellow-poplar and sweetgum

Andy W.C. Lee
Chung Y. Hse

Abstract

Previous research conducted in the laboratory pointed out several hardwood species that were either superior, comparable, marginal, or unsuitable for manufacturing cement-excelsior board (CEB). In this study, 40 full-sized boards were manufactured in a commercial production facility with the following species: yellow-poplar, sweetgum, southern pine, and a sweetgum/southern pine mixture. The properties of hardwood CEB were evaluated and compared with those of standard southern pine CEB. Results indicate that CEB made with yellow-poplar has equal or better properties than southern pine CEB. However, CEB made with all sweetgum or 50 percent sweetgum/50 percent southern pine does not meet the requirement of bending strength.

Cement-excelsior board (CEB) is a wood-based composite made from wood excelsior and portland cement. The boards are usually made with densities of 30 to 36 pounds per ft.³ (pcf) (0.48 to 0.58 g per cm³). With the porous nature of the surface, this product provides exceptional acoustical and decorative effects, making it a suitable material for roof deck, ceiling, and interior wall constructions. In addition, CEB also provides moderate structural strength and thermal insulation (3,4,7). As is the nature of a cement-bonded product, CEB possesses greater resistance to fire, moisture, fungi, and insects compared to traditional wood products.

Currently, CEB products are commercially produced in the United States mainly using southern pine and portland cement. Experiments using various hardwoods indicated that the properties of cement-bonded wood products are very dependent on wood species (2,5,9). Furthermore, study with various chemical treatments for making the hardwood CEB has shown that cottonwood was an excellent species for CEB production, yellow-poplar and sweetgum were comparable or marginal, and red oak and white oak were unsuitable under laboratory conditions (6). It was also proved that a calcium chloride solution was

very effective and economical in improving wood-cement bonding.

These previous studies on the use of hardwoods, however, were conducted in the laboratory using a small concrete blender, hand-formed mats, and small test samples. The purpose of this study was, therefore, to evaluate commercially produced full-sized CEB made from two widely available hardwood species of yellow-poplar and sweetgum.

Materials and procedures

Approximately three cords of wood for each of yellow-poplar (*Liriodendron tulipifera* L.), sweetgum (*Liquidambar styraciflua* L.), and southern pine (*Pinus* sp.) were cut from the Clemson University Forest, located at Six Mile, S.C. Southern pine, the species currently used by the CEB industry, was included for comparison. The logs, ranging from 8 to 12 inches in diameter and 63 inches long, were debarked and cut into 20-inch bolts. After dipping in a 5 percent sodium pentachlorophenate preservative solution, the bolts were stacked on pallets for air-drying outdoors for 8 weeks prior to shredding into excelsior. The excelsior was about 0.02 inch thick by 0.08 inch wide and 6 to 20 inches long. Wood excelsior was soaked in a 3 percent calcium chloride solution for about 30 seconds prior to mixing with cement. Type III portland cement (high-early-strength cement) was used for all species and species combination. Although Type III cement costs slightly more than Type I, its early strength provides better handling when boards are removed from the molds. Type III cement has been regularly used by the CEB industry. The cement/wood ratio was 2, based on oven-dry weight of wood. A

The authors are, respectively, Professor, Dept. of Forest Resources, Clemson Univ., Clemson, SC 29634-1003, and Principal Wood Scientist, USDA Forest Serv., Southern Forest Expt. Sta., Pineville, LA 71360. The authors express their gratitude to Martin Fireproof Georgia, Inc., Elberton, GA, for manufacturing the experimental panels. This paper was received for publication in September 1992.

© Forest Products Society 1993.
Forest Prod. J. 43(4):50-52.

commercial manufacturing process for CEB as described in a previous study (3) was followed for making all experimental boards.

A total of 40 full-sized boards (2 in. thick, 32 in. wide, and 96 in. long) was made in the plant with 10 boards of each of the following species: all southern pine, all yellow-poplar, all sweetgum, and 50 percent southern pine/50 percent sweetgum. A temperature recorder was connected to each stack of 10 boards. Boards were cold-pressed and cured under a pressure of 20 pounds per in.² (psi) (138 kPa) for 24 hours before removal from molds for post-curing. Three weeks after manufacturing, boards were cut into nine 10- by 32-inch test specimens with the length parallel to the longitudinal direction of the board. For each species, 42 specimens were selected at random and divided into 2 groups for conditioning at dry and soak-dry conditions, respectively. Dry condition was obtained by placing specimens at 50 percent relative humidity (RH) and 72°F until specimens reached constant weights. Soak-dry condition was obtained by soaking specimens in water for 48 hours and reconditioning them at 50 percent RH and 72°F until reaching constant weights.

After conditioning, the specimens were separated into three groups (seven specimens in each group) for the three types of load tests (equivalent uniform load, concentrated load, and sustained load) in accordance with ASTM D 2164 (1). The equivalent uniform load test, with the samples supported at two ends and the load applied at the quarter-points of the span, was used to determine the modulus of elasticity (MOE), fiber stress at the proportional limit (FSPL), modulus of rupture (MOR), and equivalent uniform load (W).

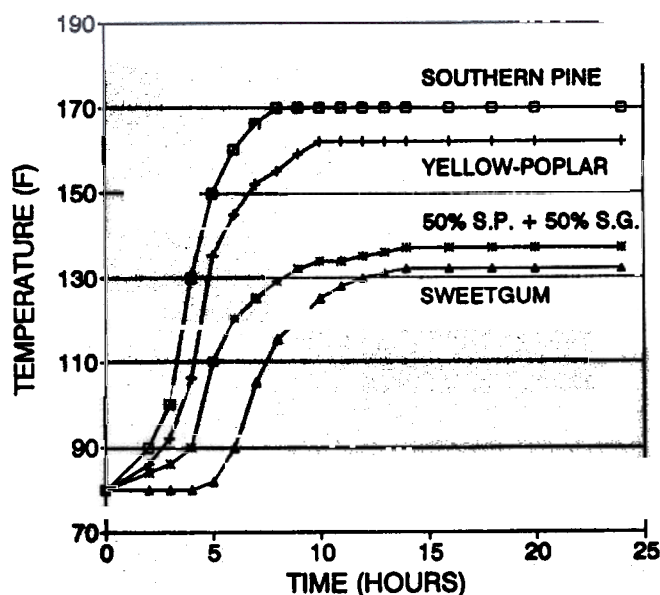


Figure 1.—Hydration temperatures of cement-bonded excelsior boards made from southern pine, yellow-poplar, sweetgum, and a 50:50 mixture of southern pine and sweetgum.

Deflection/span ratio at design load was calculated from the load test curve. The concentrated load test was conducted by loading the samples through a 4- by 4-inch-square metal plate that was placed on the sample edge at the midspan. The sustained uniform load (sag) test was performed by loading the samples with concrete blocks equal to 120 pounds per ft.² (psf) uniform load for 48 hours. Deflections at midspan were recorded during the tests.

Results and discussion

The changes in temperature for the four groups of CEB during the first 24 hours are shown in Figure 1. Temperature changes are a good indicator for cement hydration and wood-cement compatibility. It can be seen that southern pine CEB reached the highest temperature of 170°F (77°C) in 8 hours and yellow-poplar CEB reached its maximum temperature of 162°F (72°C) at 10 hours. The CEBs containing 50 percent sweetgum and all sweetgum reached their maximum temperatures of 137°F and 132°F, respectively, at 14 hours. Apparently, sweetgum generated a stronger inhibitory reaction with the cement curing.

The average moisture contents (ovendry weight base) of CEB were 9.5 and 10.8 percent, respectively, for dry and soak-dry conditions. The results of equivalent uniform load and concentrated load tests are presented in Table 1. Actual densities of CEB ranged from 30 to 33 pcf. However, the strength values were adjusted by linear regressions to a common density of 32 pcf, which was the target density for this study and for the previous study (6).

Current industrial standards (8) specify that CEB must support a maximum uniform load of 200 psf and deflection must not exceed 1/240 of the center-to-center span at the allowable design load of 50 psf. According to these requirements, all experimental boards met

TABLE 1.—Bending properties of cement-bonded excelsior boards made from southern pine, yellow-poplar, and sweetgum.^a

Property	Southern pine	Yellow-poplar	Sweetgum	50% southern pine, 50% sweetgum
Equivalent uniform load test				
MOE (1,000 psi)	140(22.5) ^b 143(20.0) ^c	130(23.1) 151(26.4)	87(19.0) 107(15.9)	114(22.1) 135(17.4)
FSPL (psi)	163(29.7) 164(24.0)	166(34.2) 220(44.3)	100(14.2) 171(67.4)	125(29.7) 197(31.3)
MOR (psi)	326(59.0) 347(62.2)	347(79.0) 452(61.0)	242(35.9) 296(83.0)	257(30.0) 331(41.1)
Deflection/span at 50 psf	1/737 1/782	1/791 1/929	1/510 1/643	1/623 1/774
Uniform load (psf)	288(57.0) 318(73.5)	328(80.9) 423(49.5)	233(40.3) 286(90.2)	226(29.8) 295(41.8)
Concentrated load test				
Concentrated load (lb.)	414(81.0) 452(41.5)	485(54.3) 531(68.3)	272(39.8) 345(65.2)	293(76.1) 343(52.3)

^a Each value is the average of seven samples. Values have been adjusted by linear regressions to a common density of 32 pcf.

^b Values in the first line represent the samples conditioned at 72°F and 50 percent RH. Values in parentheses indicate the standard deviation.

^c Values in the second line represent the samples soaked in water for 48 hours and then reconditioned at 72°F and 50 percent RH.

TABLE 2. — Deflection of cement-bonded excelsior board subjected to sustained uniform load of 120 psf.^a

Property	Southern pine	Yellow-poplar	Sweetgum	50% southern pine, 50% sweetgum
Initial deflection (in.)	0.098 ^b	0.102	0.130	0.149
	0.087 ^c	0.076	0.104	0.109
Additional deflection after 48-hr. loading (in.)	0.063	0.055	0.090	0.041
	0.028	0.017	0.064	0.036
Residual deflection 1 hr. after load removal (in.)	0.087	0.071	0.095	0.058
	0.037	0.023	0.069	0.045

^a Each value is the average of seven samples. Values have been adjusted by linear regressions to a common density of 32 pcf.

^b Values in the first line represent the samples conditioned at 72°F and 50 percent RH.

^c Values in the second line represent the samples soaked in water for 48 hours and then reconditioned at 72°F and 50 percent RH.

these standards. However, it was observed that some of the boards were up to 10 percent thicker than the target thickness of 2 inches. A more accurate comparison should be based on an MOE of 53,400 psi and an MOR of 268 psi, as reported in a previous study (6). A comparison of these values with values in Table 1 shows there were two MOR values that did not meet the requirement, one with sweetgum and the other with the 50/50 mix of southern pine and sweetgum under dry condition. Nevertheless, if these boards were soaked for 48 hours and then redried at 50 percent RH, they could meet this standard (Table 1). A t-test comparison revealed that soaking and redrying significantly improved the bending strength (MOR) of the hardwood CEB. It is believed that water-soaking may have helped the completion of cement hydration in hardwood CEB.

Currently, there are no industrial requirements for the concentrated load carrying capacity. However, from the viewpoint of construction safety, a minimum concentrated load should be specified. In the author's opinion, a concentrated load of at least 350 pounds is required. This provides at least a safety factor of 2 for an average person weighing 175 pounds.

Deflections of CEB subjected to sustained uniform load (sag) are shown in Table 2. It was noticed that the initial deflections for CEB containing sweetgum were 20 to 50 percent higher than those of southern pine and yellow-poplar CEB. This indicates that under heavy load (120 psf) these two types of CEB will have excessive sagging.

A statistical comparison using Duncan's Multiple-Range test is listed in Table 3. Comparison among the four types of boards reveals that yellow-poplar CEB is as good as, or better than, southern pine CEB. Boards containing all sweetgum or 50 percent sweetgum have significantly lower MOE, MOR, concentrated load, and higher sagging deflection when compared to southern

TABLE 3. — Duncan's Multiple-Range comparisons of properties of cement-bonded excelsior boards made from various wood species.

Property	Southern pine	Yellow-poplar	Sweetgum	50% southern pine, 50% sweetgum
MOE	A ^a A	A A	B B	A A
MOR	AB B	A A	C B	BC B
Uniform load	AB B	A A	B B	B B
Concentrated load	B B	A A	C C	C C
Initial deflection due to 120-psf load	A B	A A	B C	C C
Additional deflection due to 48-hr. sustained load	AB AB	AB A	B C	A B

^a Letter A indicates the best property among four types of boards. The same letter in the row indicates no significant difference at the 5 percent level. The first line represents the tests of samples at 72°F and 50 percent RH. The second line represents the samples soaked in water for 48 hours and reconditioned at 72°F and 50 percent RH.

pine CEB. Therefore, it is concluded that yellow-poplar can be used as a raw material for CEB production. Addition of 50 percent sweetgum to southern pine or use of all sweetgum significantly reduced strength properties and increased sagging deflection of CEB. If it is necessary to use sweetgum for production, further experiments must be conducted to determine the acceptable level of sweetgum in replacement of southern pine.

Literature cited

1. American Society for Testing and Materials. 1987. Standard methods of testing structural insulating roof deck. ASTM D 2164. Philadelphia, Pa.
2. Hofstrand, A.D., A.A. Moslemi, and J.F. Garcia. 1984. Curing characteristics of wood particles from nine northern Rocky Mountain species mixed with portland cement. *Forest Prod. J.* 34(2):57-61.
3. Lee, A.W.C. 1984. Physical and mechanical properties of cement bonded southern pine excelsior board. *Forest Prod. J.* 34(4):30-34.
4. _____. 1985. Bending and thermal insulation properties of cement-bonded cypress excelsior board. *Forest Prod. J.* 35(11/12): 57-58.
5. _____. Z. Hong, D.R. Phillips, and C.Y. Hse. 1987. Effect of cement/wood ratios and wood storage conditions on hydration temperature, hydration time, and compressive strength of wood-cement mixtures. *Wood and Fiber Sci.* 19(3):262-268.
6. _____. and P.H. Short. 1989. Pretreating hardwood for cement-bonded excelsior board. *Forest Prod. J.* 39(10):68-70.
7. _____. 1991. The latest developments in the cement-bonded wood excelsior (wood wool) board industry. In: *Proc. Inorganic Bonded Wood and Fiber Composite Materials* (A.A. Moslemi, ed.) Forest Prod. Res. Society, Madison, Wis.
8. Martin Fireproofing Georgia, Inc. 1987. Structural cement fiber roof deck systems-load table. Elberton, Ga.
9. Moslemi, A.A. and Y.L. Lim. 1984. Compatibility of southern hardwoods with portland cements. *Forest Prod. J.* 34(7/8):22-26.